1 OF 1

ED

038734

DOCUMENT RESUME

ED 038 734	24	CG 005 452

AUTHOR	Osborne, Francis H.
TITLE	The Effect of Time of Day on the Reaction to Stress. Final Report.
INSTITUTION	Morehead State Univ., Ky.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO	BR-8-C-059
PUB DATE	Jan 70
GRANT	OEG-3-9-080059-0004(010)
NOTE	33p.
EDRS PRICE	EDRS Price MF-$0.25 HC-$1.75
DESCRIPTORS	Human Development, *Laboratory Experiments, *Learning, Psychological Patterns, *Rats, Research, *Stress Variables, *Time

ABSTRACT

This study obtains evidence for the effect of time of day on learning in a stressful situation. A series of five experiments were performed to assess the effects of this variable on learning using albino rat subjects. None of the experiments provide overwhelming evidence for the effect of time of day when taken alone and each leaves questions which can only be answered by empirical test. However, as a group they seem to indicate that time of day does play an important role in learning in a stressful situation. Most forms of motivation such as fear of failure in a classroom or fear of shock in the laboratory are aversive or stressful in the Thorndikian sense of an annoying state of affairs which the organism will avoid or minimize. If the comparison holds, then although the effect would vary in its specifics, time of day might also influence human learning under stress. (Author)

BR 8-C-059
PA 24
JA

ED038734

FINAL REPORT
Project No. 8-C-059
Grant No. OEG-3-9-080059-0004(010)

THE EFFECT OF TIME OF DAY ON THE REACTION TO STRESS

January 1970

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

ED038734

Final Report

Project No. 8-C-059
Grant No. OEG-3-9-080059-0004(010)

THE EFFECT OF TIME OF DAY ON THE REACTION TO STRESS

Francis H. Osborne

Morehead State University

Morehead, Kentucky

January 1970

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgement in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

CONTENTS

TABLES

FIGURES

Summary: The purpose of this research was to obtain empirical evidence for the effect of time of day on learning in a stressful situation. There is a growing body of literature that seems to indicate that much of our daily behavior is superimposed against regular circadian fluctuations. Therefore, a series of experiments were performed to assess the effects of this variable on learning using albino rat Ss

Experiment I employed a minimum of six shock intensities in an ascending method of limits. The rat Ss were required to move to one end of a cage to avoid the shock. The dependent variable was percent avoidance. The results indicated that these Ss were more likely to avoid even minimal stress at night than during the light times of day. Experiment II involved a simple bar press escape task similar to a study by Osborne (1967) which had seemed to suggest that time of day may have been a relevant variable in the acquisition of the bar press escape response. The results provided no evidence for the effect of time of day on learning. However, the apparatus and procedure were sufficiently different to make comparisons between this experiment and the previous Osborne study difficult. Experiment III involved learning a hurdle-jump response in the presence of classically conditioned fear stimuli. Although there were certain undesirable experimenter effects, the data indicated a very regular effect of time of day. Performance was superior at night and inferior during the day. Experiment IV was a preliminary study using a one-way avoidance technique. The small number of Ss and high intersubject variability precluded statistical significance, however, these results also suggested superior performance for the evening and night hours. Experiment V measured activity levels of the Ss in a running wheel as a function of time of day. The results were consistent with the literature and indicated much greater activity at night than during the day.

None of the experiments provide overwhelming evidence for the effect of time of day when taken alone and each leaves questions which can only be answered by empirical test. However, as a group they would seem to indicate that time of day does play an important role in learning in a stressful situation. Most forms of motivation such as fear of failure in a classroom or fear of shock in the laboratory are aversive or stressful in the Thorndikian sense of an "annoying state of affairs" which the organism will avoid or attempt to minimize. If the comparison holds, then although the effect would probably vary in its specifics, time of day might also influence human learning under stress as well.

Introduction: The purpose of this research project was to obtain empirical evidence for the effect of time of day on learning in a stressful situation. It has been said that learning is the key process in human behavior. Learning influences to some degree the language we speak, our customs, attitudes and beliefs, goals: in short, learning influences essentially all of the behavior displayed by the human organism. A goal of psychology since Ebbinghaus, has been to uncover and evaluate the role of different variables on the learning process. One variable which has received much attention because of its significant role in behavior has been the effect of motivation.

Most of the work involving motivation has dealt with positive drives and rewards. This work has ranged from basic laboratory studies utilizing lower animals such as rats and their reaction to hunger and food deprivation, to more educationally applied studies involving children in the classroom working for positive rewards such as praise, candy, extra privileges, etc. One aspect of motivation which has received less attention has been the role of negative drives and rewards.

By far the most common method to study the effect of "negative reinforcement" on the learning process, has been to use electric shock. Typically, shock has been used either for punishment in a passive avoidance situation or a motivator and reinforcer in active avoidance or escape situations. The use of electric shock seems at first glance, far removed from the classroom. However, if it is assumed that electric shock is merely one possible source of stress which the organism is likely to encounter, the remoteness from practicality diminishes considerably. Most situations in life are influenced by one form of stress or another. Indeed, success in the school, home, or community is usually a measure of how well we have managed to cope with the stresses we have found in these situations. When we wish to study learning, motivation, and behavior under strictly controlled conditions, electric shock is the most frequently employed stressor because of the great precision and control we can exert over this variable.

A second variable which has received little attention in the exploration of factors affecting behavior and especially learning, has been the effect of circadian rhythms (i. e. rhythms with a recurrent cycle of approximately twenty-four hours). Most organisms (including man) are sensitive to daily light-dark and temperature cycles. Most organisms display daily physiological and behavioral cycles locked into these environmental cycles. For example, it has been shown that rats (who are normally nocturnal animals) display cycles of activity, food and water consumption, etc., which are at a maximum during the dark cycle and a minimum during the light cycle. Similarly, mice have been shown to display differential reactivity to stress as a function of time of day. For example Pizzarello, Isaak, and Chuse (1964) have shown that mice were more susceptible to whole body x-irradiation during the dark cycle as indexed by an increase in mortality rate to radiation at night.

However, variation in physiological reactivity does not necessarily mean that more integrated activity such as learning is influenced by circadian rhythm. Unexpected evidence for the effect of time of day on escape responding was found in a recent master's thesis by Osborne (1967). In this study, Ss were trained to bar press to turn off shock of different intensities in a simple escape situation. Three groups received constant shock intensities (0.6, 1.3, or 2.0 ma.) and two groups received regular or random alternated intensities (0.6 and 2.0 ma.). Individual Ss were given 6 trials per day for 11 days at the same time each day. The Ss were run hourly from 8 a.m. to 6 p.m. with all groups represented equally each hour. Examination of the data in two hour blocks indicated that performance for the Ss receiving constant shock intensities was best early (8 and 9 a.m.) and late (4 and 5 p.m.) in the day and poorest in the middle (12 and 1 p.m.) of the day. It should be noted that this study was not designed to assess the effect of time of day and only had one animal from each group at each time of day. However, the magnitude (the speed scores were at least twice as good for the constant intensity groups early and late in the day) and the regularity (the 10 and 11 a.m. and 2 and 3 p.m. groups were intermediate in performance) of the effect suggested that further investigation of the effect of time of day on performance was warranted.

Therefore, the major emphasis of our research for the past year was to obtain empirical evidence for the effect of time of day on the responsiveness to stressful stimulation and to determine what effect this would have on the learning process.

The original outline of the project proposed three different tasks designed to assess the effects of time of day on aversive learning, which were to range in complexity from simple threshold determination (Experiment I, avoidance threshold), primary reinforcement (Experiment II, escape learning) using offset of pain as reinforcement, to secondary reinforcement (Experiment III, fear conditioning) using fear reduction as reinforcement. However, procedural and methodological difficulties dictated two additional experiments which were necessary for clarification of the results. Experiment IV involved a simple one-way avoidance task and Experiment V measured activity as a function of time of day.

Experiment I. Avoidance Threshold

Studies which have found circadian effects have generally examined simple behavior such as activity, consummatory behavior, and basic physiological phenomena. Therefore, the first experiment on this project was designed to determine whether the detection of a stressor (i. e. electric shock) would vary as a function of the time of day the stress was experienced. A simple and objective technique for measuring aversion threshold was used (adapted from Campbell and Teghtsoonian, 1958) which involved presenting several intensities of electric shock ranging from below to above threshold strength. The dependent variable with this technique was the percentage of time S experienced the shock. It was assumed that if S could not detect the shock or did not find it aversive, S would remain on the shock side of the apparatus about 50 percent of the time (i. e. the percent time expected by chance). The response necessary to escape the shock was intentionally simple to minimize learning effects.

Method: Subjects: The subjects were 16 male albino Wistar rats supplied by Harlan Industries of Cumberland, Indiana. The Ss were approximately 100 days old at the start of the experiment and weighed 275 ± 25 grams. During the course of the experiment Ss were housed individually in cages which were isolated in living cubicles (1 cubicle per S). The Ss were allowed food and water ad lib. Food, water, and cage care were administered only after the Ss had been run. Therefore, Ss were not disturbed by general laboratory routine. The Ss were maintained on a 12 hour light-dark cycle with the onset of light coming at 8:30 a.m. and the offset coming at 8:30 p.m.[1] The light in the experimental cubicle was programmed to turn on and off with the living quarters, however, the short interconnecting corridor was lit at all running times and provided sufficient light for Es to transport Ss from their home cages to the experimental cubicles.

Apparatus: Preliminary testing indicated that the lowest range (50 uA) of a standard Grason Stadler shock generator and grid scrambler, was above threshold. Therefore, the shock generator was modified to deliver four additional shock intensities of 14, 18, 23, and 31 uA. The shock was delivered to the Ss through the grid floor of a Lehigh Valley rat shuttle box located in the adjacent experimental cubicle. Shock was programmed and regulated by means of additional relays, tape programmer, and switches. Shock duration was measured to the nearest .01 second on two Industrial Timer stop clocks.

Procedure: The S was removed from his home cage and placed into the shuttle box in the experimental cubicle within 15 minutes of each of the eight times of day. A single ascending series of shock intensities was used consisting of 14, 18, 23, 31, 50 and 60 uA in that order. Each intensity was administered for 10 minutes in which the S could shut off the shock by moving to one side of the shuttle box. If S returned the original side, the shock was resumed. The stop clocks were used to measure the cumulative time Ss received shock in each of five 2 minute intervals for a total of 10 minutes. At the end of the 10 minute period the shock was automatically shut off if S was receiving it at the time. The intensity was increased one setting and a new 10 minute interval was begun. If S was on the safe side at the beginning of the interval, the safe side was switched such that S would have to move to the other side to turn off the shock. The rationale behind this procedure was that if the shock intensity was below threshold, S would be in the safe and shock side equally often (i. e. 50% of the time for each). However, as the shock reached threshold S would tend to spend more and more time in the safe side. The session was terminated after the sixth intensity (60 uA) if S had avoided the shock side for 95% of each of the last 4 minute periods for the last two shock intensities (i. e. 50 and 60 uA). If S had not met this criterion, the intensities were increased every 10 minutes until the S did successfully avoid at least 95% of the time in the last two 4 minute periods. Additional intensities used were: 80, 100, 130, 160, 200, and 250 uA. Half of the 16 Ss were randomly assigned to each of the 4 experimenters. Each S-E combination was assigned to one of the eight starting times for

[1]All times specified in this report are Eastern Standard Time.

session 1. Following this, each S was run 27 hours later by the same E until S had received 9 sessions which consisted of each of the eight times of day and a replication of the first time of day. Although the avoidance response involved was very simple (moving from one end of a cage to the other), the first session was considered a training session and only the last 8 sessions were evaluated to minimize the effects of learning. The remaining 8 Ss were similarly assigned following completion of the first 8 Ss and the procedure repeated.

Results: The percentage scores were analyzed by means of a treatments by treatments by subjects analysis of variance (Winer, 1962. Pp. 289-290). The eight times of day were one treatment and six shock intensities (14, 18, 23, 31, 50, and 60 uA) were the second treatment.[2] Although the effect of time of day failed to reach significance ($F=1.78$, $df=7/105$, $p=.10$), shock intensity ($F = 20.61$, $df = 5/75$, $p < .01$) and the interaction between shock intensity and time of day ($F = 1.92$, $df = 35/525$, $p < .01$) were statistically significant. Figure 1 presents percent avoidance as a function of shock intensity for each of the eight times of day. Inspection of this figure reveals the interaction between intensity and time of day is complex. If it is assumed that 50 percent avoidance is the level of avoidance expected by chance, then all eight times of day exceed 75 percent avoidance (i. e. the aversion threshold) with the greatest shock intensity (i. e. 60 uA). However, lower shock intensities vary in their effect. The pattern of behavior suggested by the figure is that avoidance decreases with increasing shock intensity for the first few intensities and then avoidance increases for the 10 a.m., 1 p.m., 4 p.m., and 7 p.m. times, while avoidance is nearly directly proportional to shock intensity for the 10 p.m., 1 a.m., 4 a.m., and 7 a.m. running times. Figure 2 illustrates this point much more clearly. In this figure the four times from 10 p.m. to 7 a.m. and 10 a.m. to 7 p.m. are averaged into separate "dark" and "light" curves. Therefore, it would appear that although aversion threshold as operationally defined by the shock intensity avoided 75 percent of the time, does not differ substantially for the different times of day, the behavior displayed at lower intensities does differ during the dark versus the light periods.

Conclusions: The major result of this experiment was that there was a difference in behavior displayed by the same Ss at low shock intensities as a function of time of day. In general the results indicated that performance was poorer (i. e. less avoidance) during the light hours than the dark hours. The rat has two main natural reactions to a stressful situation: one is to freeze or remain immobile and the other run and escape. The above results suggest that the rat is more likely to use the former during the day and the latter at night. This does not necessarily mean that he is less able to detect a stressful stimulus during the day, only that his performance in terms of avoiding the situation is different.

---

[2]The individual scores on which the analysis was performed appear in Appendix A.

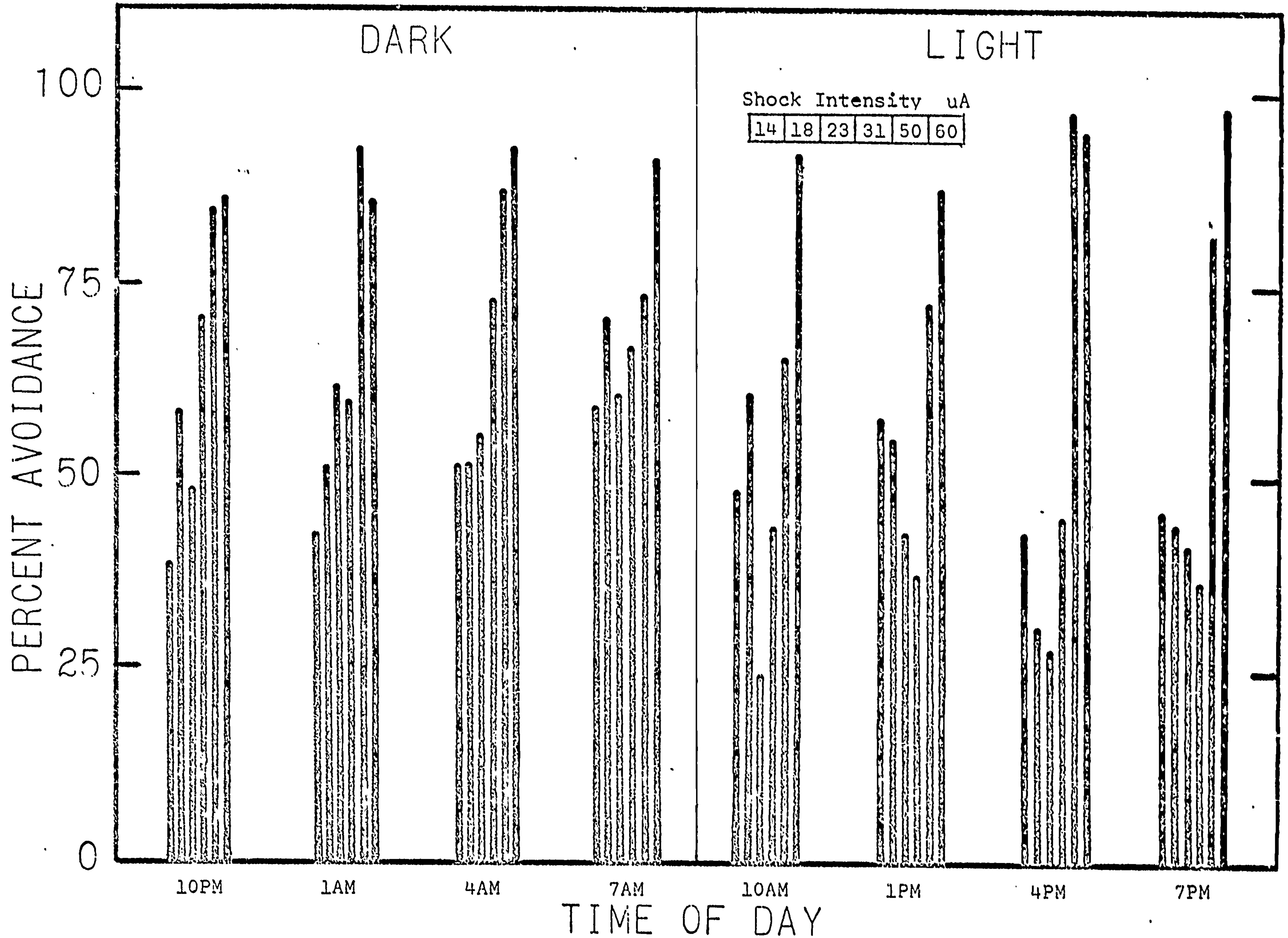

Figure 1. Percent avoidance as a function of shock intensity for each of the eight times of day.

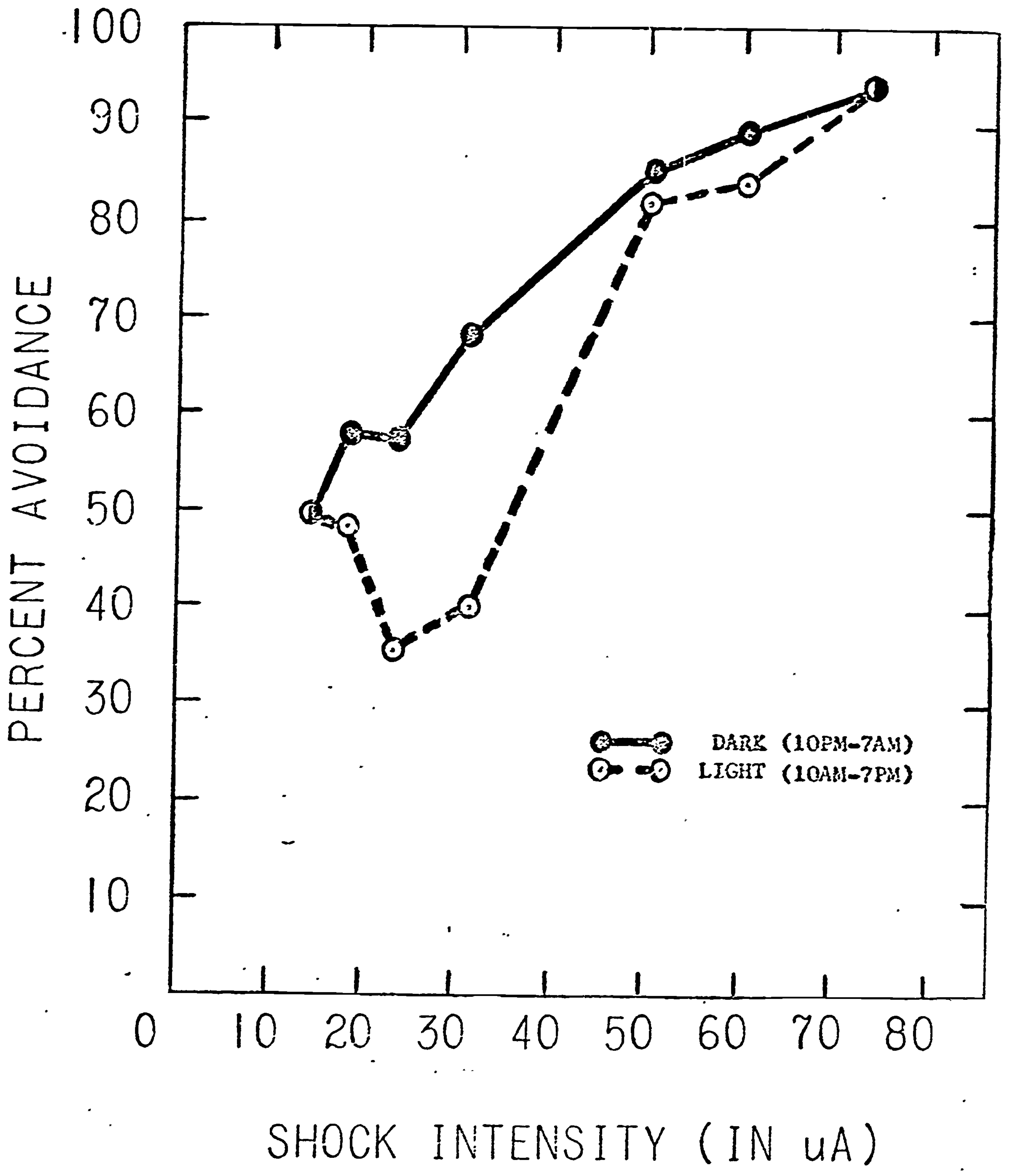

Figure 2. Percent avoidance as a function of shock intensity for the daily dark and light periods.

Experiment II. Escape Learning

The second experiment was designed to replicate, in part, Osborne's earlier (1967) escape study which had suggested a possible variation in escape performance as function of time of day. Basically the technique involves presenting electric shock which can be terminated by Ss pressing a lever (i. e. bar press escape response).

Method: Subjects: The Ss were 128 male Albino Wistar Rats randomly assigned to the experimental conditions and were approximately 100 days old at the start of the experiment. The same living conditions were used including light-dark cycle and experimental cubicle as in Experiment I.

Apparatus: A standard Grason Stadler shock generator and grid scrambler was used to deliver high (1.0 ma) or low (.5 ma) shock to S's feet through the grid floor of a Lehigh Valley rat shuttle box located in the adjacent experimental cubicle. A Gerbrands rat lever was mounted at one end of the shuttle box and programmed to turn off the shock when S presses it.[3] The same programming and timing apparatus was used as in Experiment I.

Procedure: The S was removed from his home cage and placed into the shuttle box in the experimental cubicle within 15 minutes of each of the eight times of day. A single S was used at only 1 time of day and 2 shock intensities for a total of 128 Ss. Sixty seconds after placement in the apparatus the shock was turned on and remained on until the S pressed the bar. Fifteen trials per day with an intertrial interval of 60 seconds were given for 4 consecutive days at the same time of day for a total of 60 trials.

Results: The latency scores were transformed into speed scores (reciprocals) and analyzed by means of a 2 x 8 factorial analysis of variance in which the two shock intensities and the eight times of day were the factors.[4] The effect of shock intensity approached significance ($F = 3.23$, $df = 1/112$, $.05 < p < .10$). No comparison (including time of day) achieved significance.

Conclusions: The results of this experiment did not provide evidence for the effect of time of day on learning of an escape task. However, there were several methodological differences between this and the earlier Osborne (1967) study which may have accounted for this. For example, the differences in test apparatus, massing of trials, etc., may have impeded learning and obscured the differences which might have existed in performance as a function of time of day.

---

[3]Use of the shuttle box which is larger than most operant conditioning chambers, has movable floor, etc., was necessitated by the unavailability of a standard operant chamber.

[4]The individual scores on which the analysis was performed appear in Appendix B.

Experiment III. Fear Conditioning

Originally, it had been planned to use a bar press avoidance task to study secondary reinforcement as a function of time of day. However, since an operant conditioning chamber was unavailable, it was decided that fear conditioning would serve the same purpose. This procedure consists of pairing some previously neutral stimulus (CS) with inescapable electric shock (UCS) in a typical classical conditioning paradigm. Following conditioning S is allowed to escape the CS by jumping to another compartment (hurdle-jump response). It is assumed that the procedure conditions an emotional fear response to the CS which provides the motivation for learning the instrumental jump response even though shock is no longer encountered in this phase of the procedure.

Method: The Ss were 48 naive male albino rats with the same age, weights, supplier, and living conditions as Experiment I. The light-dark cycle was altered slightly to light onset at 8 a.m. and offset at 8 p.m. Because the nature of the experiment required Ss to be handled each trial in the hurdle-jumping phase, a dim (60 w) light was maintained in the experimental cubicle at all times.

Apparatus: A Lehigh Valley rat shuttle box was modified such that the standard center partition insert containing a three inch diameter hole, was equipped with a vertically sliding guillotine door and miscroswitch, and served to divide the box into two compartments. Opening of the door turned on the combination light and sonalert CS in the hurdle-jumping phase of the experiment. Further modifications of the shuttle box included replacement of the plastic lid with two wooden doors covering each of the two compartments formed by the center partition. Black electrical tape was placed on the two end walls of the shock compartment and a plastic floor installed over the grids of the safe compartment to make these two compartments discriminably different. A Grason Stadler shock generator was modified so that a variable autotransformer provided a 145 VAC scrambled shock input through a 11K ohm resistor to the grids of the shock compartment. The purpose of altering the shock source from a constant current to a matched impedence source (see Cornsweet, 1963) was to minimize the Ss learning some sort of freezing response which might compete with the desired hurdle response. The 145 VAC input was chosen on the basis of preliminary work indicating that this voltage elicited about as much activity from the Ss as the 1.0 ma shock input used in the escape learning task. Shock was programmed and regulated by the same apparatus as used in the earlier studies and response latencies measured by the same stop clocks.

Procedure: A given S was run for four consecutive days at the same time of day with either forward conditioning (FC) in which the light-sonalert CS preceded the two second shock (UCS) by four seconds and terminated with the UCS, or backward conditioning (BC) in which the CS came on for six seconds immediately following the offset of the two second UCS. The purpose of the two conditioning groups was to assess the effectiveness of the CS. However, it should be noted that the shock box itself was a powerful CS.

Day one consisted of handling for twenty minutes and exploration of the shuttle box for twenty minutes. Day two was the initial conditioning day on which each S received twenty FC or BC trials. Day three started with five additional conditioning trials followed by twenty-five hurdle-jumping trials in which S was placed in the shock compartment facing the guillotine door. Ten seconds later, the door was opened, causing the CS to turn on simultaneously. If S jumped to the safe compartment, the CS was automatically turned off and the door closed. If S failed to jump within sixty seconds, the door was closed and he was placed in the safe compartment by E. In either case, S remained in the safe compartment for thirty seconds before he was replaced into the shock compartment for the beginning of the next trial. Day four consisted of twenty-five additional hurdle-jumping trials.

Three Es each ran a squad of four randomly assigned Ss at each of four times of day (6 a.m., 12 noon, 6 p.m., and 12 midnight) for a total of 48 Ss. The Ss were run in a counterbalanced conditioning order (FC, BC, BC, FC) and the starting times adjusted so that the average starting time for the squad corresponded to the nominal times noted above. The dependent variable was the latency of the hurdle-jump response and the independent variables were time of day, type of conditioning (FC vs. BC), and the three experimenters.

Results: The latency scores were converted to speed scores (i. e. reciprocals of latency) and the data analyzed by a trend analysis of variance with experimenter, conditioning, and time of day as between Ss factors and ten blocks of five trials as the repeated measure.[5] The main effects of time of day ($F = 4.21$, $df = 3/24$, $p < .05$) and trials ($F = 28.25$, $df = 9/216$, $p < .01$) were significant as was the effect of experimenter ($F = 6.55$, $df = 2/24$, $p < .01$). Three of the interactions involving trials were also significant at the .01 level: trials by experimenters ($F = 5.15$, $df = 18/216$); trials by conditioning ($F = 2.72$, $df = 9/216$); and trials by experimenters by time of day ($F = 2.40$, $df = 54/216$). The trials by experimenter interaction represented the tendency of one E's Ss to display less learning over trials. The trials by conditioning interaction indicated that the FC group was actually poorer than the BC group at least on the early trials. Observation of the Ss during the experiment suggested that the FC Ss tended to freeze at the onset of the CS, which would compete with the jumping response, while the BC Ss tended to remain more mobile during the CS, which was a kind of safety signal for these Ss.

Of greater interest, for our purposes, was the effect of time of day. Figure 3 presents the mean reciprocal of latency scores for each of the four times of day as a function of trials on each of the two hurdle-jumping days. Inspection of the figure reveals a regular increase in performance over trials on the first hurdle-jumping day, reflecting learning. The scores on the second day dropped slightly probably because shock was no longer present,

---

[5]The individual scores on which the analysis was performed appear in Appendix C.

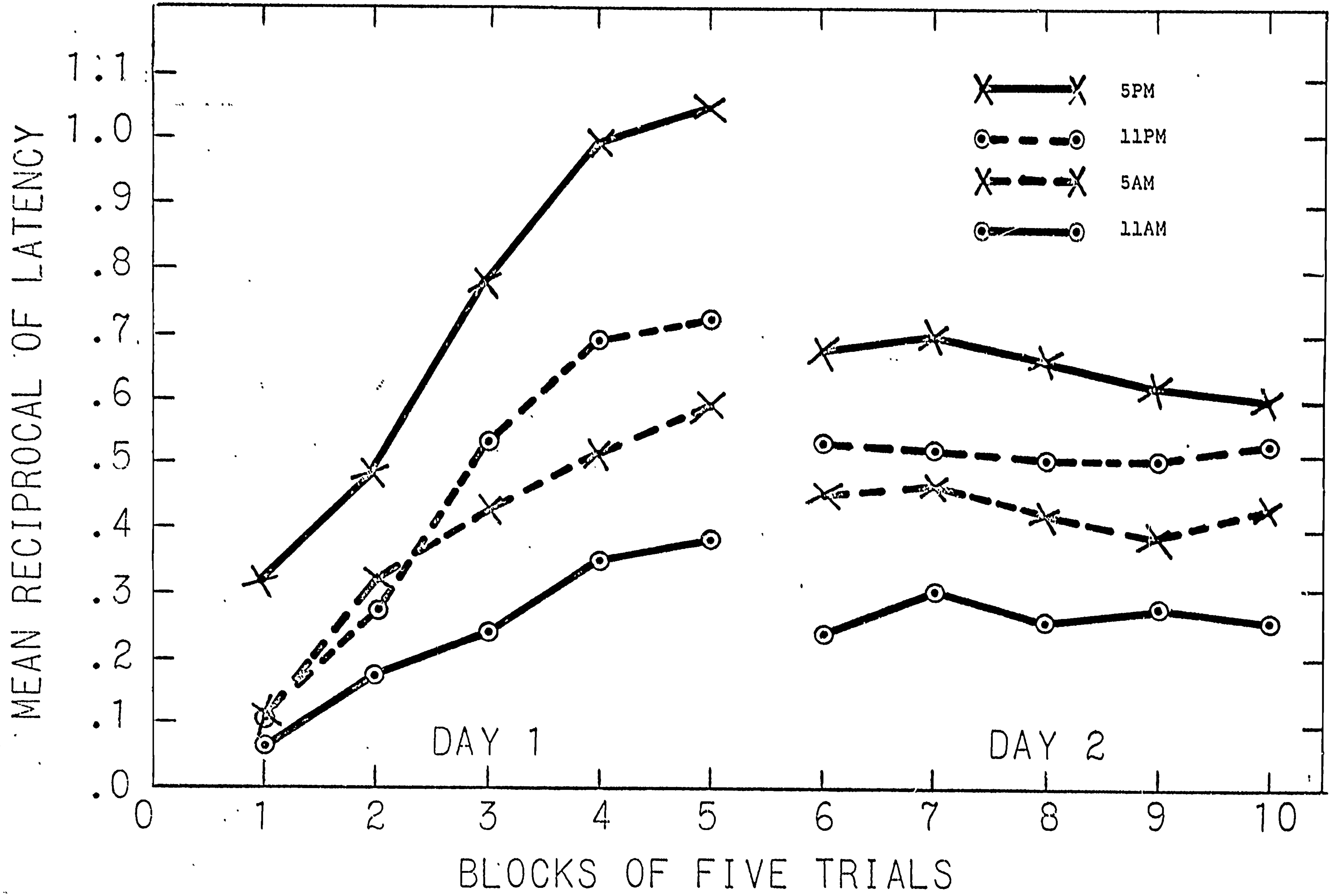

Figure 3. Mean reciprocal of latency scores for each of the four times of day as a function of trials on each of the two hurdle jumping days.

resulting in some extinction. However, the regular ordering of the four time of day groups is very striking following the initial trials. Figure 4 summarizes this even more clearly, where overall performance is presented as a function of time of day. Inspection of Figure 4 indicates that performance is best at 6 p.m. and poorest at 12 noon with the 12 midnight and 6 a.m. points falling between.

Conclusions: Although some experimenter effects tend to obscure the results, it would appear that the learning of a secondarily reinforced (i. e. fear reduction) hurdle-jump response varied as a function of time of day, with learning superior at the 6 p.m. and 12 midnight times and inferior at the 6 a.m. and 12 noon times. These results are consistent with Experiment I where it was found that avoidance of a minimal shock was greater in the dark hours than the light hours. Unlike Experiment I, these Ss were run in the light at all times making the mere presence or absence of light less likely an explanation of the effect and suggests the possibility of some sort of internal "biological clock" as suggested Bolles and de Lorge (1962). However, the existence of experimenter effects and the interaction of this variable with time of day permits only tentative interpretation of the data.

Experiment IV. One-Way Avoidance

One type of simple avoidance task which was possible with the shuttle-box was a one-way avoidance task. Since the avoidance paradigm includes elements of both the escape and fear conditioning paradigms, it was decided to run a preliminary investigation involving one-way avoidance.

Method: Subjects: Twenty-four naive albino Wistar rats were used with six Ss run at each of four times of day (6 a.m., 12 noon, 6 p.m., and 12 midnight). The living conditions, cubicles, light-dark cycle and apparatus were the same as in Experiment III (except that the plastic covering for the safe compartment grids was omitted).

Procedure: Prior to avoidance training, each S was handled for twenty minutes and allowed to explore the apparatus for twenty minutes. Avoidance training consisted of placing the S in the shock compartment, and the guillotine door opened causing the onset of the CS. If S did not jump within five seconds, the shock would come on and remain on until S terminated both the shock and CS by jumping into the safe compartment. A jumping response to the CS alone is termed an avoidance response and a response to the shock - CS combination, an escape response. The inter-trial interval was thirty seconds and each S received twenty trials or was run until he achieved a criterion of ten consecutive avoidance responses, whichever was longer. If an S did not achieve criterion within 50 trials, S was terminated and arbitrarily assigned a trials to criterion score of fifty-one.

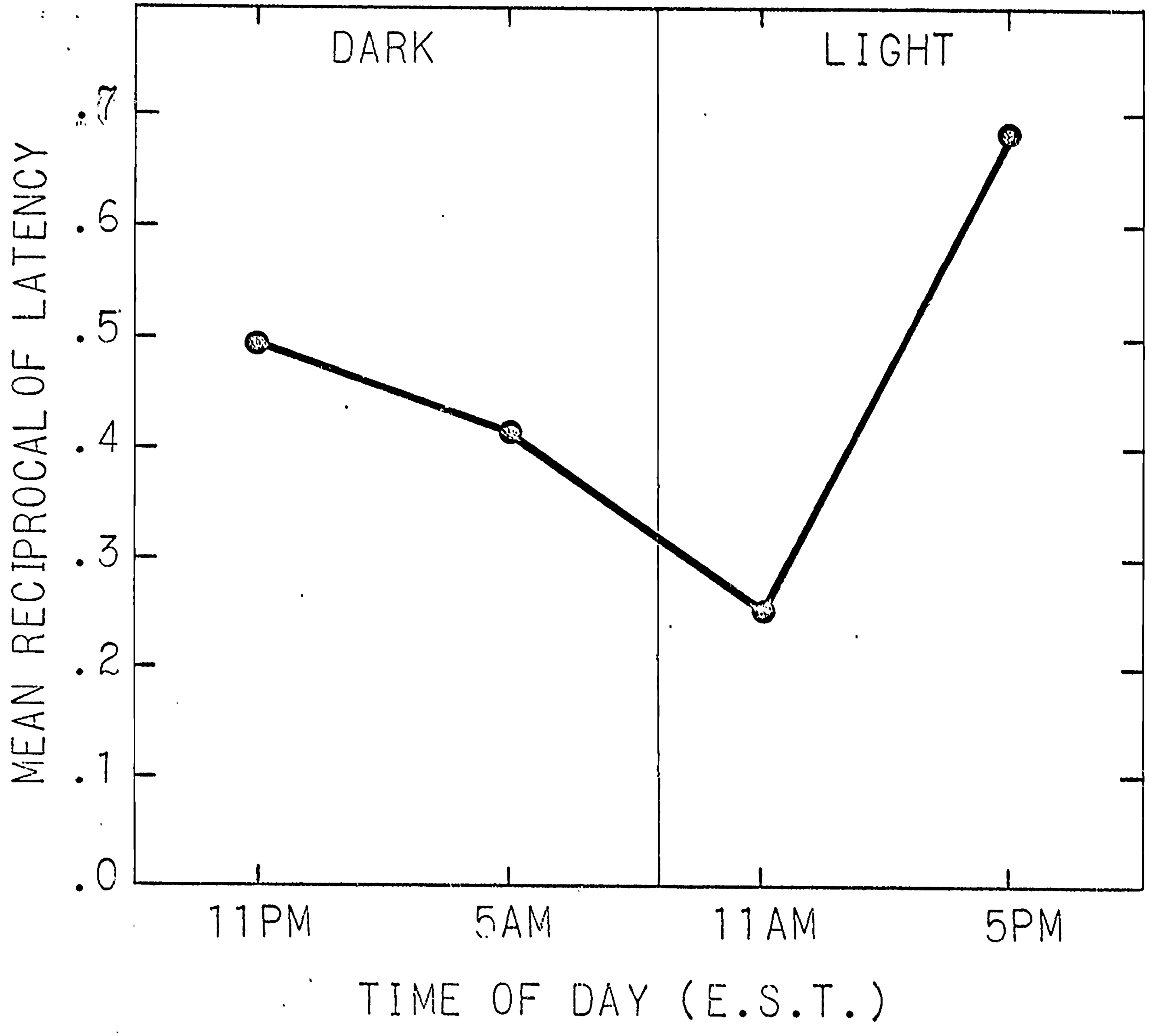

Figure 4. Mean performance on a fear conditioning task as a function of time of day.

Results and Conclusions: The trials to criterion scores and the number of avoidance responses in blocks of five trials for the first twenty trials were evaluated by separate analyses of variance.[6] No comparison involving time of day attained statistical significance. Examination of the data indicated a trend for the 6 p.m. and 12 midnight groups to display superior performance over the 6 a.m. and 12 noon groups. However, the low number of Ss and large variability between Ss tended to obscure any effect. Also, further testing indicated that omitting the plastic floor on the safe compartment grids was probably responsible for the generally poor performance. Therefore, before any conclusions concerning the presence or absence of an effect of time of day on performance in a one-way avoidance task, the experiment would have to be repeated with a greater number of Ss and with more perceptually distinct shock and safe compartments.

Experiment V. Activity Measures

The final experiment undertaken was the assessment of activity as a function of time of day.[7] The purpose of this experiment was two-fold: first to set the activity cycle of our Ss against what had been found in the literature; and second, to determine whether the times we had been sampling were optimal in terms of the activity cycle.

Method: Subjects: The Ss were 8 naive male albino Wistar rats similar to the Ss used in the preceding studies. One S was discarded because of apparatus failure, leaving a total of 7 Ss. The light-dark cycle remained at 8 a.m. - 8 p.m. light, 8 p.m. - 8 a.m. dark as in Experiments IV and V.

Apparatus and Procedure: Eight Standard Lafayette Instrument Company activity wheels were used, complete with living compartments and mechanical counters. Sufficient food and water was placed into the living compartment to last the entire 4 1/2 days of the experiment and minimize disruption of the Ss. The counter readings were recorded every 6 hours for the first 2 1/2 days until the activity cycles had stabilized, following which the counter readings were recorded every 3 hours (2 a.m., 5 a.m., 8 a.m., 11 a.m., 2 p.m., 5 p.m., 8 p.m., and 10 p.m.).

Results and Conclusions: Figure 5 presents the mean percent daily activity as a function of time of day. Inspection of this figure reveals that activity was lowest during the day and increased many-fold at night. The inversion at 8 a.m. is interesting because it indicated an increase in activity in anticipation of the light onset (i. e. 8 a.m.). Similarly, the 8 p.m. activity level indicates an increase in anticipation of the light offset (i. e. 8 p.m.).

---

[6] The individual scores on which these analyses were performed appear in Appendix D.

[7] This experiment should probably have been performed first in the series, however, the equipment and facilities were not available until late in the project.

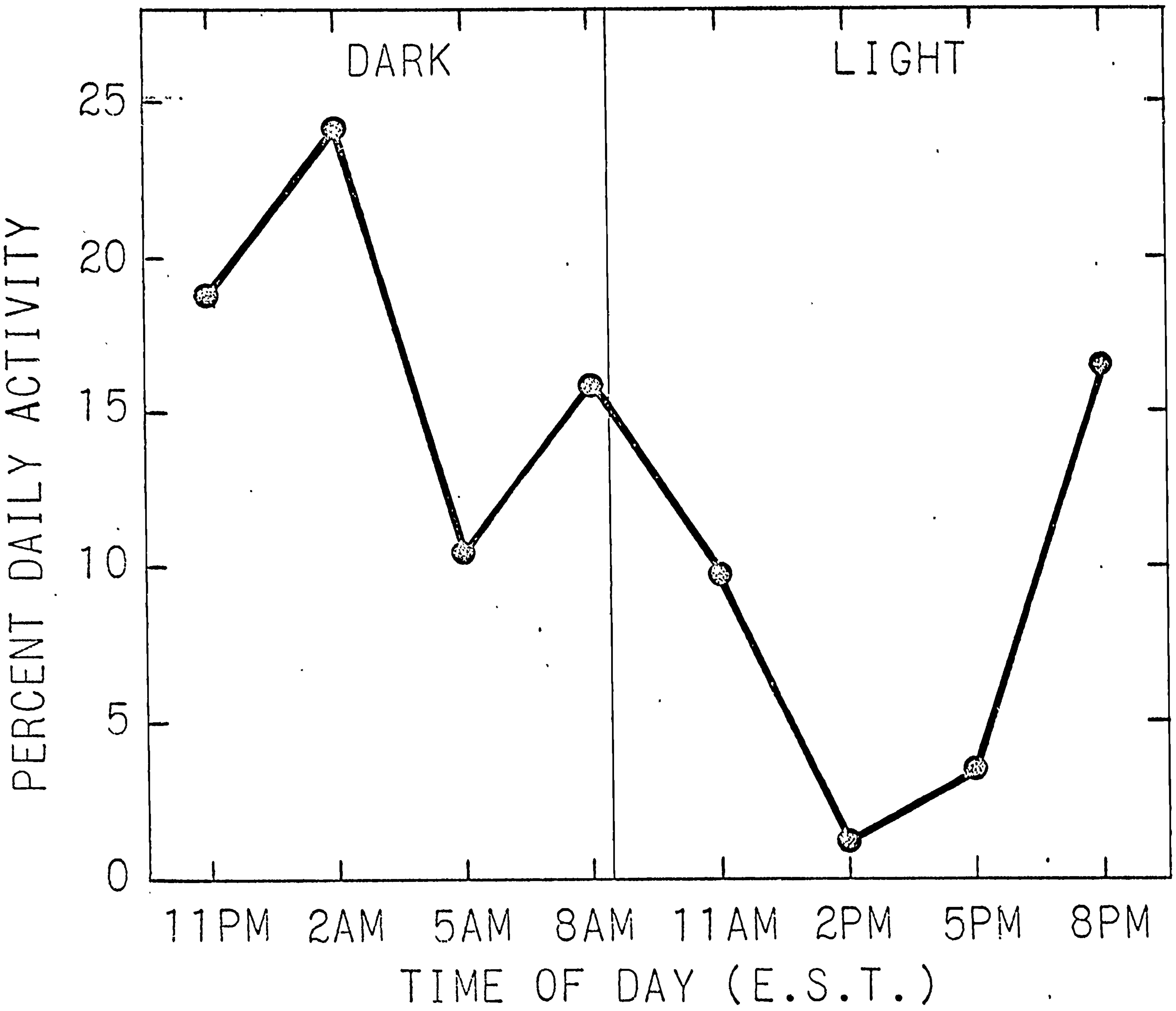

Figure 5. Mean percent daily activity as a function of time of day.

In general, the data agree with the literature, indicating the not suprising fact that the Ss were more active at night. However, the times chosen for the previous studies (especially Experiments III and IV) did not coincide too well with the maxima and the minima of Figure 5. For example, the 5 and 11 a.m. times resulted in roughly equivalent activity, while the 5 p.m. time indicated less and the 11 p.m. time indicated greater activity than the 5 and 11 a.m. times. Recalling that the 5 and 11 p.m. times produced performance superior to the 5 and 11 a.m. times in Experiment III, it would appear that activity levels were not directly responsible for the differences in performance.

Conclusions and Recommendations: To summarize, five experiments were performed which were designed to measure the effect of time of day on performance of various tasks by white rats. Four of these experiments involved the use of an aversive or stressful stimulus (i. e. electric shock). The tasks ranged in complexity from simple aversion threshold and activity determination (Experiments I and V), the learning of more complex escape response in the presence of a more severe stressor (Experiment II), to the learning of an instrumental response to remove fear provoking stimuli (Experiments III and IV). Although the results frequently lacked statistical significance, the body of evidence indicated that performance, whether simple activity or more complex learned responses, was superior at night for these normally nocturnal animals.

Experiment I indicated that Ss were more likely to avoid even minimal stress at night than during the light. The mild threshold shock used in this experiment resulted in "freezing" behavior during the light hours, such that Ss received an even greater duration of shock than would be expected by chance. There were two possible explanations of this behavior which would not require any particular appeal to circadic response to stress. One involved the fact that the tendency for freezing behavior was generally observed when Ss performed under light conditions and avoided more readily under condition of darkness. If it is assumed that rats, as with many animals, have two natural competing responses to stress; running or freezing (i. e. playing "possum") and that the freezing response might be more practical during the day when a "poorsighted" animal (such as the rat) would be more vulnerable, then the results of Experiment I would not indicate differential performance, only different response tendencies. However, later experiments in which Ss were all run in light conditions also showed a decrement during the normally light hours (Experiments III and IV), indicating that the mere presence or absence of light may not be enough to account for the results. A second possibility was indicated by the activity experiment in which activity levels were found much lower during the day than at night. It is possible that with the procedures used in Experiment I, lowered activity might result in apparently poorer performance during the day and conversely, heightened activity produce superior performance at night. However, although percent avoidance at most intensities was greater at night, there was no difference between times of day at the lowest level of shock (i. e. 14 uA) indicating that responsiveness to the shock stimulus, rather than activity was being measured in Experiment I as a function of time of day.

Experiment II, which involved an escape task, provided no evidence for the effect of time of day on learning, unlike Osborne's (1967) earlier study. However, the apparatus and procedure employed were substantially different (e. g. shuttle box versus an operant conditioning chamber) which may account, at least in part, for this discrepancy in results.

Experiment III used a fear conditioning and hurdle-jumping technique. Although there were certain undesirable experimenter effects, the data indicated a very regular effect of time of day. Performance was superior at night and inferior during the day. Fear conditioning has a methodological advantage over most avoidance procedures in assessing effects on secondary negative reinforcement, in that performance in the instrumental learning stage is not confounded with primary drive effects (i. e. shock is no longer present in the hurdle-jumping stage). The presence or absence of light was controlled in this experiment by testing all Ss under conditions of light. Also, performance on this task did not necessarily correlate with the activity levels measured in Experiment V, at least at the specific times tested. Therefore, it would appear that this experiment provided good evidence for the possible operation of some sort of "biological clock" mechanism (see Bolles, & De Lorge, 1962; Biological Laboratory, 1960) affecting the learning of a task at different times of day.[8] However, none of the experiments actually place the effect of time of day in a neat package. Each of the experiments described above leave questions which can only be answered by empirical test.

Educational Relevance of the Research: One major aim of this research has been to gain a greater understanding of the action of circadic effects on the complex task of learning and to suggest the possible role this variable may play in human learning as well. It is always presumptious and perhaps dangerous to overgeneralize from animal to human research. However, as Miller (1959, p. 204) has noted, one aspect of animal research is to determine what questions are relevant for human research. In general, animal research affords much greater control of potentially relevant variables.

For example, Jennings (1969) attempted to assess the effect of class time on student performance. Ten sections of an introductory economics class were taught at different times of day ranging from 8:55 a.m. to 3:10 p.m. and in two or three class meetings per week (i. e. MWF: Monday-Wednesday - Friday; TT: Tuesday - Thursday; TTS: Tuesday - Thursday - Saturday). However, the four instructors who taught the classes were partially confounded with time of day and days the sections were offered. Also, although the ten sections were reasonably similar in terms of their mean grade point averages at the beginning of the semester, students were not randomly assigned to sections which may well have introduced uncontrolled

[8]It should be noted that the statement, "time of day may have an effect on behavior," is not meant to imply that time per se effects behavior. Obviously, time, as such, can have no effect. However, certain mechanisms, physiological and psychological, may vary concomittantly with time and produce the effect noted.

systematic variation between the sections other than time of day and day of week. To Jennings' credit, he recognized most of these shortcomings of his study and in the typical practical setting of the University curriculum, most of them would be difficult to control. The only statistical differences Jennings found was between the TTS sections and the remaining sections (TT - p.m., MWF - p.m., and MWF - a.m.) in which the TTS section was significantly poorer.

A better or at least more rigorous method to control for some of the deficiencies in the Jennings' study would be to establish a pool of Ss available over a broader range of times. Randomly assign these Ss to various times, and using material controlled for difficulty, method of presentation, etc., assess the similarities and differences in learning and retention at different times of day.

There are several recent studies which have indicated circadian effects on man's performance in a variety of tasks. Blake (1967 a) found that his Ss improved in performance on five choice, vigilance, card sorting, letter cancellation, and calculation tasks, and that digit span decreased as a function of time of day. Blake (1967b) also found circadian differences in body temperature as a function of an introversion-extroversion measure. Thor (1962) also found differences on a time estimation task as a function of time of day.

Learning economics in the classroom may seen far removed from electric shock in the rat laboratory, but throughout most of this report, we have been careful to use electric shock as an example of one type of stressor. As others have pointed out (e.g. Selye, 1956; Mowrer, 1960), most forms of motivation such as hunger, thirst, fear of failure in a classroom, or fear of shock in the laboratory are aversive or stressful in the Thorndikian sense of an "annoying state of affairs" which the organism will avoid or attempt to minimize. If the comparison holds, then although the effect would probably vary in its specifics, we might well expect time of day to influence human learning under stress as well.

References:

Biological Laboratory. Biological clock. In., Cold Spring Harber symposia on quantitative biology., Vol. 25. Cold Spring Harbor, Long Island: B. J., 1960.

Blake, M. J. F. Time of day effects on performance in a range of tasks. Psychonomic Science, 1967, 9, 349-350. (a)

Blake, M. J. F. Relationship between circadian rhythm of body temperature and introversion-extroversion. Nature, 1967, 215, 896-897. (b)

Bolles, R. C., & deLorge, J. The rat's adjustment to a-diurnal feeding cycles. Journal of comparative & physiological Psychology. 1962, 55, 760-762.

Campbell, B. A., & Teghtsoonian, R. Electrical and behavioral effects of different types of shock stimuli on the rat. Journal of comparative & physiological Psychology, 1958, 51, 185-192.

Cornsweet, T. N. The design of electric circuits in the behavioral sciences. New York: Wiley, 1963.

Jennings, W. N. The influence of class time on student performance. Unpublished Manuscript. Randolph-Macon College, Ashland, Virginia, 1969.

Miller, N. E. Liberalization of basic S-R concepts: Extensions to conflict behavior, motivation, and social learning. In., Koch, S. (Ed.) Psychology: A study of a science. Vol. 2. New York: McGraw-Hill, 1959, Pp 196-292.

Mowrer, O. H. Learning theory and behavior. New York: Wiley, 1960.

Osborne, F. H. Varied shock and simple escape. Unpublished master's thesis. Syracuse University, 1967.

Pizzarello, D. J., Isaak, D., & Chua, K. E. Circadian rhymicity in the sensitivity of two strains of mice to whole body radiation. Science, 1964, 141, 286-291.

Selye, H. The stress of life. New York:: McGraw-Hill, 1956.

Thor, D. H. Diurnal variability in time estimation. Perceptual and Motor Skills, 1962, 15, 451-454.

Winer, B. J. Statistical principle in experimental design. New York: McGraw-Hill, 1962.

APPENDIX A

AVERSION THRESHOLD INDIVIDUAL SCORES

TABLE 1

EXPERIMENT I

PERCENT AVOIDANCE FOR EACH SUBJECT AT EACH TIME OF DAY AND SHOCK INTENSITY

Time of Day	Shock Intensity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Subject Number															
1 AM	14	40	23	36	75	80	0	57	24	0	69	53	62	56	100	0	15
	18	100	100	100	100	57	0	89	100	0	87	20	0	0	0	0	80
	23	85	100	0	50	100	61	100	100	0	30	100	0	100	70	0	100
	31	100	80	76	39	66	95	100	100	61	31	0	15	0	100	0	100
	50	100	100	100	100	100	100	100	100	100	86	100	98	100	100	0	100
	60	96	100	100	100	99	100	99	100	100	81	100	0	100	100	0	100
4 AM	14	47	66	50	95	68	0	50	46	46	30	58	89	100	7	0	69
	18	74	91	8	76	69	0	3	95	68	60	20	47	100	52	0	58
	23	2	100	88	100	93	93	100	45	12	0	100	17	45	0	0	94
	31	100	82	99	89	79	100	100	100	100	20	100	24	100	0	0	76
	50	98	92	100	100	100	100	78	100	100	49	100	75	100	100	0	100
	60	100	100	100	100	100	100	100	100	100	93	100	94	100	100	0	100
7 AM	14	75	89	76	73	58	58	26	63	62	24	68	77	7	94	14	81
	18	90	96	80	42	66	81	63	0	80	78	53	58	100	88	54	100
	23	55	100	89	19	56	100	81	0	37	11	98	57	100	100	71	0
	31	100	3	100	8	98	100	69	10	70	92	0	80	100	100	39	100
	50	0	100	100	100	100	100	54	0	40	86	95	100	100	100	0	100
	60	100	78	100	100	100	100	95	0	98	96	100	100	100	100	0	100
10 AM	14	0	0	44	72	39	0	11	62	83	76	58	92	80	100	35	28
	18	0	0	60	75	75	0	76	100	71	0	100	100	65	100	88	67
	23	0	0	100	0	85	100	10	0	0	0	0	0	0	99	0	8
	31	0	0	100	91	92	0	97	0	0	0	82	0	100	0	41	100
	50	0	0	100	92	100	0	100	100	73	100	100	0	100	88	0	100
	60	0	79	100	100	100	100	100	100	100	46	100	0	100	100	53	100

1 PM	14	59	97	86	78	22	100	7	2	66	87	69	67	31	100	64	0
	18	51	0	100	74	11	0	10	0	62	97	100	100	100	100	76	0
	23	100	2	96	0	2	0	0	0	0	100	47	0	100	100	42	100
	31	0	0	100	0	3	0	86	7	0	100	100	0	0	100	0	100
	50	98	93	98	72	100	86	87	7	11	100	100	0	100	100	0	100
	60	100	0	100	100	98	100	100	100	100	100	100	100	98	100	2	100
4 PM	14	48	3	52	64	81	0	34	0	0	87	0	53	100	100	61	3
	18	100	100	100	0	0	0	9	100	0	0	0	26	0	11	52	3
	23	0	0	100	0	14	0	0	0	0	0	0	0	100	100	74	.84
	31	0	100	100	0	80	0	32	0	0	0	100	0	19	100	100	100
	50	100	100	100	100	100	100	100	100	8	29	100	56	100	100	100	100
	60	87	100	100	100	100	100	100	6	44	100	100	100	100	100	100	100
7 PM	14	19	100	100	3	91	0	44	100	0	38	0	99	29	0	41	73
	18	0	0	100	100	91	0	8	0	0	100	0	0	100	81	45	100
	23	100	0	97	39	8	0	100	0	100	0	0	0	0	0	64	70
	31	0	0	100	90	100	0	0	0	0	0	90	0	0	61	89	62
	50	100	100	100	100	100	0	95	100	0	0	100	100	100	100	100	100
	60	100	100	100	100	100	98	98	100	0	100	100	0	100	100	100	100
10 PM	14	28	19	42	34	53	0	31	5	0	67	25	100	50	83	0	84
	18	17	100	100	100	44	69	100	44	0	84	85	0	0	100	0	100
	23	100	21	44	11	69	100	100	6	0	21	0	0	100	93	0	100
	31	100	100	100	70	76	100	100	89	0	99	0	2	100	100	0	93
	50	100	100	100	100	100	100	70	100	0	100	100	100	100	100	0	100
	60	87	100	100	100	100	98	100	100	0	97	100	100	96	100	0	100

APPENDIX B

ESCAPE TASK INDIVIDUAL SCORES

TABLE 2

EXPERIMENT II ESCAPE TASK

MEAN RECIPROCAL OF LATENCY FOR EACH SUBJECT
AT EACH TIME OF DAY AND SHOCK INTENSITY

Time of Day	Shock Intensity	Subject Number 1	2	3	4	5	6	7	8	Mean	S.D.
1AM	.5	1.30	1.68	1.88	.39	1.27	1.68	1.09	.72	1.12	.52
	1.0	1.66	1.58	2.26	1.76	.79	1.22	1.97	2.37	1.70	.52
4AM	.5	.39	.55	1.36	.79	1.87	1.05	1.54	2.12	1.21	.62
	1.0	.27	.18	2.11	1.10	1.78	1.49	1.06	1.93	1.24	.73
7AM	.5	1.46	1.88	1.78	1.55	.94	.70	.74	1.73	1.35	.48
	1.0	1.77	1.49	1.79	1.43	1.14	1.46	1.04	1.23	1.42	.27
10AM	.5	2.09	1.32	1.14	1.59	1.16	1.09	1.50	1.31	1.40	.33
	1.0	1.36	.79	1.62	2.54	1.82	.72	1.25	.81	1.36	.62
1PM	.5	1.34	1.75	1.10	1.13	.78	1.10	1.89	1.27	1.30	.36
	1.0	2.06	1.01	1.27	1.72	1.25	1.80	2.39	1.88	1.67	.46
4PM	.5	1.04	.52	.87	1.76	1.60	1.94	1.96	1.19	1.36	.53
	1.0	1.16	1.34	1.61	1.76	1.22	1.36	1.00	2.99	1.56	.68
7PM	.5	1.25	1.67	1.85	1.86	1.92	1.29	.79	2.39	1.63	.50
	1.0	1.16	1.34	1.61	1.76	1.22	1.36	1.00	2.99	1.56	.68
10PM	.5	.56	1.57	.64	1.81	.50	1.41	1.64	.80	1.12	.54
	1.0	.71	1.09	1.99	1.89	1.17	1.67	1.73	1.27	1.44	.45

APPENDIX C

FEAR CONDITIONING INDIVIDUAL SCORES

TABLE 3

EXPERIMENT III FEAR CONDITIONING

MEAN HURDLE RESPONSE RECIPROCAL OF LATENCY FOR EACH SUBJECT FOR EACH TIME OF DAY, EXPERIMENTER, CONDITIONING GROUP, AND BLOCK OF TRIALS

Time of Day	Experimenter	Conditioning Group	Trial Block 1	2	3	4	5	6	7	8	9	10
6AM	1	FC	.05	.35	.67	.65	.81	.70	.98	.86	.71	.97
		FC	.26	.62	.79	.98	1.01	.89	.96	.97	.77	.85
		BC	.16	.67	.55	.73	.93	.81	.70	.83	.87	.67
		BC	.10	.44	.39	.81	.78	.50	.65	.60	.68	1.12
	2	FC	.02	.02	.02	.09	.10	.02	.12	.31	.19	.03
		FC	.09	.08	.06	.03	.19	.15	.02	.02	.02	.02
		BC	.31	.42	.53	.42	.40	.50	.20	.02	.02	.02
		BC	.09	.62	1.11	.80	1.18	1.06	1.23	1.12	1.18	.93
	3	FC	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
		FC	.03	.08	.15	.22	.06	.14	.10	.07	.05	.02
		BC	.03	.06	.40	.74	.71	.02	.44	.23	.21	.50
		BC	.16	.39	.51	.70	.91	.65	.23	.07	.02	.02
12 Noon	1	FC	.05	.14	.12	.14	.42	.16	.66	.17	.06	.02
		FC	.02	.02	.05	.06	.03	.05	.05	.02	.02	.02
		BC	.04	.48	.50	.90	1.05	.32	.28	.58	.51	.55
		BC	.11	.41	.37	.62	1.01	.40	.49	.33	.60	.26
	2	FC	.10	.25	.39	.62	.42	.77	.60	.66	.60	.70
		FC	.20	.42	.85	1.07	1.00	.77	1.10	.95	1.06	.94
		BC	.03	.18	.37	.67	.55	.31	.34	.29	.33	.48
		BC	.02	.02	.02	.02	.02	.03	.04	.04	.02	.02
	3	FC	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
		FC	.03	.06	.06	.03	.02	.02	.02	.02	.02	.02
		BC	.09	.03	.03	.02	.02	.02	.02	.02	.02	.02
		BC	.04	.05	.07	.05	.02	.05	.09	.02	.02	.02

6PM	1	FC	.23	.56	.86	1.19	1.11	1.30	1.24	1.16	1.20	1.15
		FC	.23	.60	.86	1.23	1.40	.96	1.04	.69	.73	.63
		BC	.38	.83	1.15	1.66	1.66	.95	1.00	1.30	1.60	1.84
		BC	.02	.06	.24	.80	1.17	.05	.02	.02	.02	.02
	2	FC	.02	.23	.37	.53	.67	.41	.05	.11	.02	.11
		FC	.02	.02	.02	.17	.21	.11	.27	.16	.13	.02
		BC	1.70	.70	1.10	1.29	1.80	1.10	.49	.43	.12	.02
		BC	.22	.20	.86	.93	.83	.37	.60	.63	.06	.02
	3	FC	.02	.03	.10	.05	.03	.02	.02	.02	.02	.02
		FC	.15	.63	1.06	1.08	.83	.74	.96	1.16	.94	1.02
		BC	.50	.93	1.18	1.39	1.58	.64	.78	1.10	1.11	.89
		BC	.30	.97	1.47	1.62	1.28	1.42	1.47	1.16	1.42	1.43
12 Mid	1	FC	.14	.65	1.06	1.69	1.66	.87	1.20	1.46	1.19	1.47
		FC	.02	.02	.78	1.10	1.31	.98	1.27	1.28	1.73	1.74
		BC	.02	.21	.87	1.03	1.01	1.27	1.22	.90	1.34	.99
		BC	.02	.10	.71	.75	.94	.77	.43	.40	.36	.29
	2	FC	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
		FC	.07	.17	.43	.35	.81	.48	.66	.74	.18	.18
		BC	.52	.88	.97	1.72	1.47	1.44	1.14	1.08	1.10	1.59
		BC	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
	3	FC	.03	.21	.18	.33	.16	.20	.09	.02	.02	.02
		FC	.03	.39	.49	.81	.71	.11	.16	.11	.12	.04
		BC	.19	.34	.41	.10	.05	.04	.02	.02	.02	.02
		BC	.23	.26	.41	.39	.55	.17	.02	.02	.02	.02

APPENDIX D

ONE-WAY AVOIDANCE INDIVIDUAL SCORES

TABLE 4

EXPERIMENT IV ONE-WAY AVOIDANCE TASK

NUMBER OF AVOIDANCE RESPONSES FOR EACH SUBJECT, IN BLOCKS OF FIVE TRIALS, AT EACH TIME OF DAY

12 Noon — Trial Block

S#	1	2	3	4
1	2	4	5	5
2	1	4	5	5
3	0	0	2	1
4	3	4	5	5
5	0	0	0	1
6	1	2	4	5
Mean:	1.2	2.3	3.5	3.7

12 Midnight — Trial Block

S#	1	2	3	4
1	3	4	5	5
2	0	1	2	4
3	1	3	5	5
4	1	5	3	5
5	2	4	3	4
6	1	4	5	5
Mean:	1.3	3.5	4.2	4.7

6 PM — Trial Block

S#	1	2	3	4
1	2	5	5	5
2	0	3	5	5
3	1	4	4	5
4	0	5	5	4
5	2	4	5	5
6	0	0	1	1
Mean:	.8	3.5	4.2	4.2

6 AM — Trial Block

S#	1	2	3	4
1	1	4	4	4
2	1	3	4	4
3	1	1	4	4
4	0	1	3	1
5	0	2	0	2
6	2	5	4	5
Mean:	.8	2.7	3.2	3.3